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The LCDROOT analysis package*

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The North American Linear Collider Detector group has developed simulation and analysis program packages. LCDROOT is one of the packages, and is based on ROOT and the C++ programing language to maximally benefit from object oriented programming techniques. LCDROOT is constantly improved and now has a new topological vertex finder, ZVTOP3. In this proceeding, the features of the LCDROOT simulation are briefly described.

I. INTRODUCTION

For various studies for future Linear Collider experiments, the North American Linear Collider Detector group (LCD) has developed simulation and analysis program packages. LCDROOT is one of the packages for event generation, fast and full detector simulations, and event analyses. In LCDROOT, the simulators are designed to have the flexibility of changing any component of the detector parameters, i.e, geometry and performance, to study detector requirements in detail.

LCDROOT is based on ROOT [1] which is an object oriented framework, and the C++ programming language. In the ROOT framework the basic utilities and services, such as I/O and 3D graphics, are provided. ROOT provides a large selection of HEP-specific utilities such as histogramming and fitting. ROOT also has a C++ command interpreter. Due to these very powerful features, a lot of experimented groups use ROOT. Currently we support LCDROOT on AIX, Linux, Sun and Windows platforms.

II. EVENT GENERATOR

For event generation, we support PANDORA [2] with an interface using PYTHIA [3, 4] and TAUOLA [5], for parton showering, hadronization, and tau decays. The generator includes beam polarization, beamstrahlung, and initial state radiation, which are very important features for future Linear Collider studies. PANDORA is written in C++ and can be directly handled within LCDROOT. Hence PANDORA is used as our main generator. We also support the PYTHIA [3, 4] event generator with a C++ interface class. In order to support other generator outputs, LCDROOT also handles HEPEVT common blocks using the FNAL StdHep I/O package [6].

III. SIMULATION AND EVENT RECONSTRUCTION

LCDROOT supports both fast and full detector simulations. The fast simulator is designed to provide a fast and flexible physics analysis environment, while the full simulator is for detailed detector studies. Detector geometry is specified by a text file translated from XML, and geometry parameters are easily changed in LCDROOT.

The fast simulation is based on parametrized position and energy smearing, and it makes tracks and clusters directly from the generated particle information. In the fast simulation, charged particles within the magnetic field follow helical trajectories, and their momenta and positions are smeared according to their error matrix. The error matrices are given by a look-up table method based on momentum and $\cos\theta$ of charged particles. The error matrices include off-diagonal elements to give added realism.

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Electrons, photons, and hadrons produce clusters in the electromagnetic (EM) and hadronic (HAD) calorimeters. Here, one cluster is made from one particle, and energies and positions of clusters are smeared. To consider the detector granularity and cluster width, which is typically a few units of Moliere radius, we merge the clusters when the angular separation between clusters is less than θ_{max}, where θ_{max} is a size of the detector granularity.

The position of the interaction position is also smeared. We assume σ_x=σ_y=2 μm and σ_z=6 μm [7].

We use GISMO [8] for the full simulation. The full simulation outputs simulation data in binary format using SIO [9]. LCDROOT reads the SIO binary format for event reconstruction. Using the digitized outputs from the full simulation, we reconstruct charged tracks and clusters. In the reconstruction of the full simulated data, we postpone the track reconstruction. Instead, we make charged tracks by smearing, using exactly the same procedure as in the fast simulation, but we also apply a minimum tracker-hit cut. Calorimeter clusters are made by gathering the hits which are from the same particle. Energy and position of the cluster is obtained from the energy sum, and the energy-weighted average of associated Calorimeter hits, respectively.

Comparing the full and fast simulations, the most significant difference is in the Calorimetry. It is important to improve the parameterization of the fast simulator Calorimetry to have a more realistic detector response, which we hope to implement in the near future.

IV. EVENT ANALYSIS TOOLS

For the physics analysis, there are several useful tools in LCDROOT. We provide Thrust finding and 3 kinds of Jet finding (based on JADE, JADE-E and DURHAM algorithms) programs. There is also an event display for LCDROOT.

In the energy flow analysis, neutral clusters are selected by the absence of a track and cluster association. For this analysis, we provide methods which extrapolate the particles to the cluster cylindrical radius.

For heavy flavor tagging, we provide two kinds of topological vertexing algorithms which are described in the next section.

V. HEAVY FLAVOR TAGGING

Building on the success of the CCD-based vertex detector (VTX) at the SLC/SLD experiment [10, 11], we strongly believe that a CCD-based VTX will provide the optimal performance in future Linear Collider experiments. Taking advantage of the precise 3-D spatial points provided by such a detector, powerful topological vertexing techniques were developed by SLD [12]. The algorithms naturally associates tracks with the vertices where they originated and can reconstruct a full b/c-meson decay chain, i.e, primary, secondary, and tertiary vertices. Using the reconstructed secondary/tertiary vertex, the invariant mass of the tracks associated with a decay is used to identify jet flavor (mass tag technique [13]). This combination of the techniques gives the best heavy-flavor-jet tagging performance in e^+e^- colliding experiments at present. We have previously ported the original topological vertexing source code, ZVTOP, written in Prepmort, to C++ to fit natively into the LCDROOT simulation environment. The main feature of ZVTOP3 is the ability to reconstruct one-prong decay vertices, giving it better reconstruction efficiency. During Snowmass 2001 we succeeded in implementing this functionality into LCDROOT. Figs. 1 and 2 show b/c-quark jet tagging efficiencies and purities comparing the performance of ZVTOP and ZVTOP3, clearly demonstrating the enhanced capabilities of this algorithm. We plan to continue our efforts to improve the flavor-tagging efficiency and purity since it is such an essential part of any Linear Collider physics program.

VI. SUMMARY

In this report, we briefly introduce the simulation and analysis tools based on ROOT for the LCD group. The tools are constantly being improved and can be obtained via the URL, `http://www-sldnt.slac.stanford.edu/nld/New/Docs/LCD_Root/root.htm`. Feedback from the users is highly welcomed.

[1] R. Brun and F. Rademakers, Nucl. Instrum. Meth. **A389**, 81 (1997).
[2] M. E. Peskin (1999), arXiv:hep-ph/9910519.
[3] T. Sjostrand, Comput. Phys. Commun. **82**, 74 (1994).

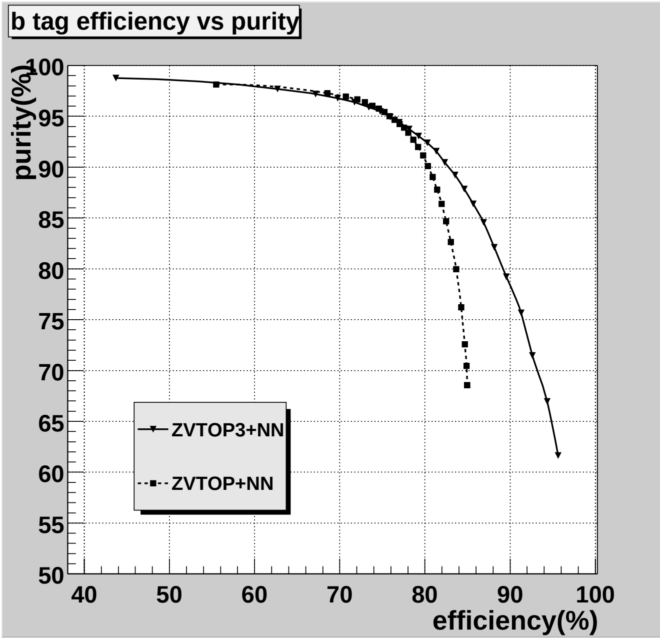

FIG. 1: Performance of b-jet flavor tagging in $Z^0 \to q\bar{q}$ events generated at $\sqrt{s} = 91.26\mathrm{GeV}$.

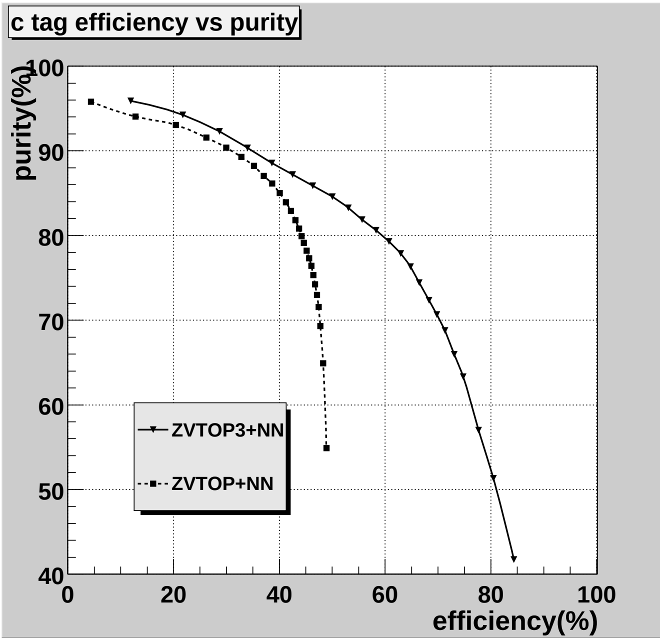

FIG. 2: Performance of c-jet flavor tagging in $Z^0 \to q\bar{q}$ events generated at $\sqrt{s} = 91.26\mathrm{GeV}$.

[4] T. Sjostrand et al., Comput. Phys. Commun. **135**, 238 (2001), arXiv:hep-ph/0010017.
[5] S. Jadach, Z. Was, R. Decker, and J. H. Kuhn, Comput. Phys. Commun. **76**, 361 (1993).
[6] L. Garren and P. Lebrun (1998), URL `http://www-pat.fnal.gov/stdhep.html`.
[7] T. Abe (2001), arXiv:hep-ex/0102022.
[8] T. H. Burnett (1993), in proceedings of the International Conference on Monte Carlo Simulation in High-Energy and Nuclear Physics - MC 93, Tallahassee, FL, 22-26 Feb 1993.
[9] A. Waite (1999), URL `http://www-sldnt.slac.stanford.edu/nld/new/Docs/FileFormats/s\%io.pdf`.
[10] K. Abe et al., Nucl. Instrum. Meth. **A400**, 287 (1997).
[11] T. Abe (SLD), Nucl. Instrum. Meth. **A447**, 90 (2000), arXiv:hep-ex/9909048.
[12] D. J. Jackson, Nucl. Instrum. Meth. **A388**, 247 (1997).
[13] K. Abe et al. (SLD), Phys. Rev. Lett. **80**, 660 (1998), arXiv:hep-ex/9708015.